Tune drift meeting

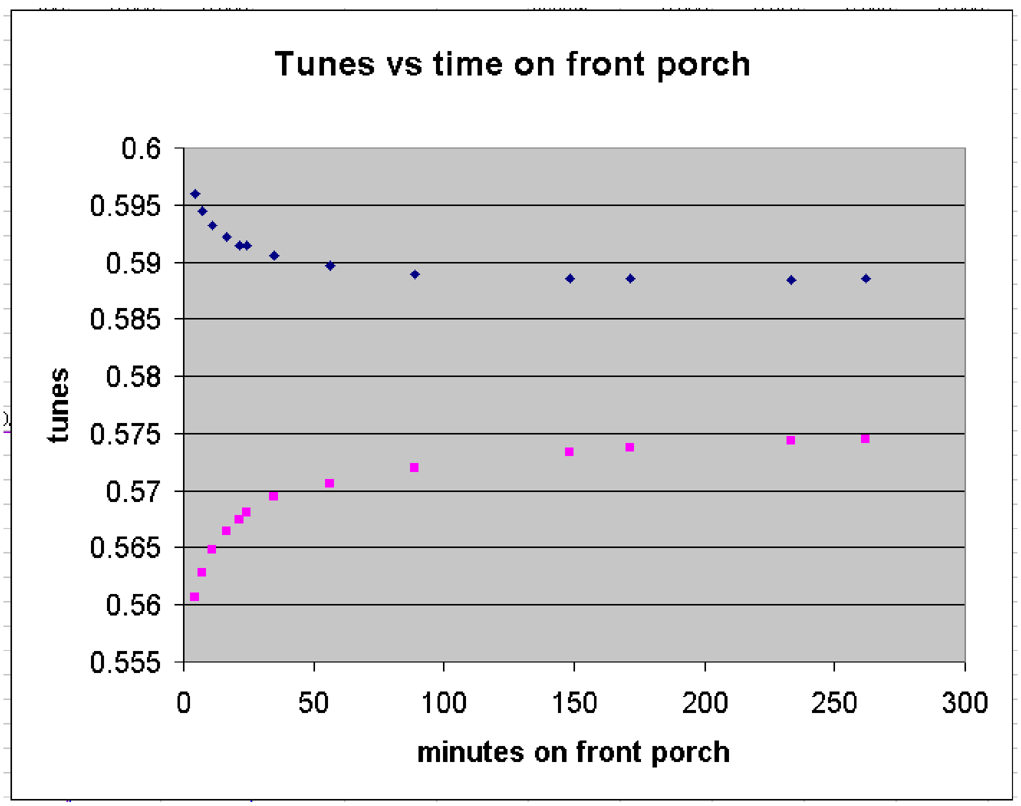
Mike Martens 5/9/02

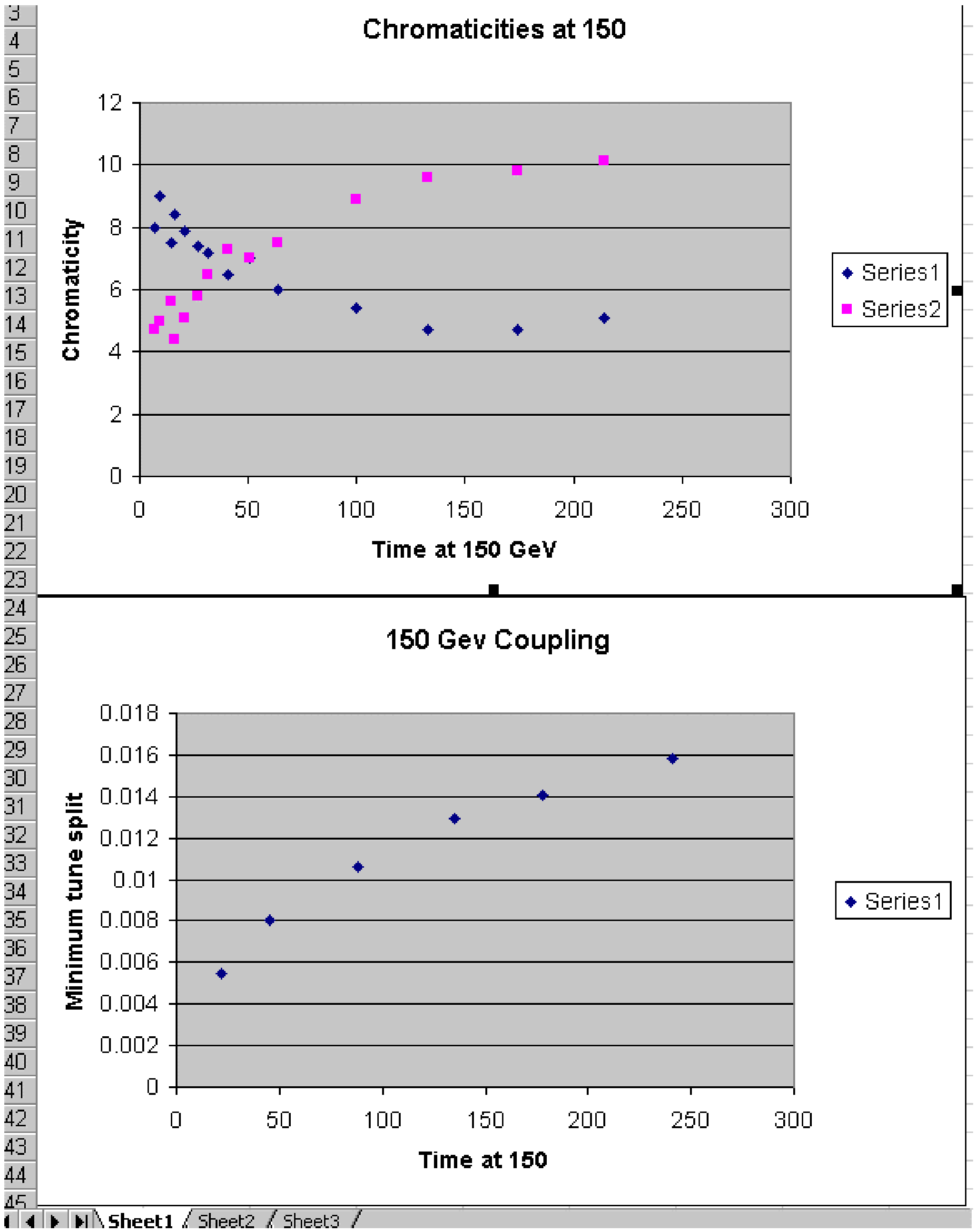
Mike Martens, Vladimir Shiltzev, Valeri Lebedev, Yuri Alexahin, Jerry Annala met to discuss ideas concerning the tune and coupling drift observed at 150 Gev.

Nature of the problem

While sitting at 150 Gev the tunes in the Tevatron drift by about 0.01 and the coupling drifts introducing a minimum tune split of about 0.01. Several measurements of these types have been made during Run II and a search of the logbook for the year 2001 shows measurements on 3/24/01, 4/8/01, 4/14/01, 4/20/01, and 8/28/01. This problem appears to be new for Run II since it was not observed during Run I.

The following measurements from 8/20/01 demonstrate this effect. These are measurements of the tunes, minimum tune split, and chromaticity as a function of time at 150 Gev. It was noted by Jerry that the b2 chromaticity correction was not optimized at that time and this explains the drift in the chromaticity.




Chromaticities at 150
Chromaticity
12
10
8
6
4
2
0
0
50
100
150
200
250
300
Time at 150 GeV
Series1
Series2
150 Gev Coupling
Minimum tune split
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
50
100
150
200
250
300
Time at 150
Series1
Sheet1
Sheet2
Sheet3

The drifting tunes, coupling, and chromaticity make it difficult to maintain the proper Tevatron parameters at 150 Gev during shot setup and the same phenomenon might explain the tune excursions at the start of the Tevatron ramp. Recently Yuri has been using the octupole circuits in the Tevatron to improve proton lifetime by reducing the chromaticity and introducing amplitude dependent tune shifts via the octupoles. During shot setups he has been adjusting tunes, coupling, chromaticity, and feeddowns and has observed that this must be done every shot setup to ensure good tune values and therefore good lifetime values. In fact waiting for a little as 30 minutes after tuning up can result in degraded lifetime.

Mike has been adjusting the tunes up the ramp and added an extra breakpoint in the ramp at 153 Gev. There is concern that the tune and coupling drifts are related to persistent currents and there may be an "unwind" of the skew quad component at the start of ramp which makes tuning at the start of the ramp more difficult.

In order to improve operations and maintain constant tunes without continual effort we decided to look into the cause of the drifting tunes in order to eliminate the source of the drift or find a method for reliably compensating for the drift.

Possible sources of drift and measurements

Several ideas were discussed at this meeting and several studies plans were introduced.

A single rogue element is causing the drift.

Could a single element such as a Tevatron main quad or low beta quad be acting flaky and explain the source of the coupling? If this is true Valeri believes we could detect the source of coupling my making difference orbit measurements at the very start of the 150 Gev porch and again about 30-60 minutes later. If the focusing change is limited to a single quadrupole we should be able to detect it since we can measure a 1% change in the focusing strength using the 1-bump difference orbit technique. Jerry and Valeri will try to implement this measurement in the next week or two.

A combination of orbit offset and sextupole field is causing the drift.

Perhaps the orbit is not passing through the center of the b2 field in the main dipoles and through the center of the chromaticity sextupoles. If this is true then the changing b2 component of the dipoles and the changing current in the chromaticity sextupoles can produce a feeddown effect causing changes in the tune.

One possible source of orbit offset is a radial position offset due to an energy mismatch. In fact it is possible for the horizontal orbit as measured in the BPM's to go through the center of the BPMs, yet not go through the center of the dipole fields. This "scalloped" orbit effect is possible if there is an energy mismatch between the RF frequency and the main bend bus strength that is then compensated for by the horizontal dipole correctors. However this would only explain a tune drift and not the coupling drift since a horizontal orbit offset in the chromaticity sextupoles does not create a skew quad component. Perhaps the Tevatron contains other sources of coupling which are sufficient to cause vertical orbit distortions in the sextupole fields. Jerry calculated that a vertical orbit distortion of 18 mm would be required in a single chromaticity sextupole would be required to explain the change in coupling that is observed at 150 Gev if the source of the coupling was a vertical orbit distortion in one of the chromaticity sextupoles.

Measurements by Annala on 4/12/01 suggest that the changes in the chromaticity sextupoles during the b2 wind up are not sufficient to account for the change in tune. The measured tune shift from the changing current in T:SF and T:SD is only about 1/10 of the amount needed to explain the changes.

More recently Yuri made some measurements of change in tune versus the strength of the chromaticity sextupole circuit T:SD which shows we are on not going through the center of the T:SD sextupoles. The table below shows the change in horizontal and vertical tune when a –0.25 Amp change was made in the T:SD circuit.

RF frequency offset	Change in vertical tune	Change in horizontal tune
-40 Hz	+0.0025	-0.0008
0 Hz	+0.0007	-0.0003
+40 Hz	-0.0008	+0.0003

This measurement suggests that we are centered in the T:SD sextupoles (on the average) if we change the RF frequency by +20 Hz which corresponds to a –0.38 mm offset in the closed orbit.

It was decided to investigate more carefully the amount of tune drift caused by the sextupole fields in the dipole fields and chromaticity sextupole fields. Part of the goal for this measurement will be the determination of the amount of tune drift created by the changing current in the chromaticiy sextupoles and the amount of tune drift explained by the b2 component of the dipole magnets. Mike will look into this analysis and suggest some measurements to make.

Is the b2 correction algorithm tuned up correctly?

Recently Yuri has started to use the octupole circuits at 150 Gev to add tune spread versus amplitude to the proton beam thereby allowing us to reduce the chromaticity and improve the proton lifetime. Adjusting the Tevatron parameters for this mode of operation requires setting the chromaticities so 2-4 units. Since the b2 correction algorithm corrects for chromaticity changes of some 20 units, even an error of 10% in the b2 correction algorithm could change the chromaticity by several units. Jerry believes that the system is tuned up such that the chromaticity varies by less than 1-2 units. (Although it was off by about 5 units in August of 2001 before more refined adjustments were made.)

Jerry will look into investigating the validity of the b2 correction algorithm. Also we can eliminate the need for a dry squeeze if the b2 correction algorithm and TCHROM OAC are tuned up for after store conditions.

Chromaticity measurements

To help facilitate chromaticity measurements it is worth trying to implement Dave McGinnis' idea to measure the chromaticity using FM modulation. This would make it easier to measure the chromaticity as a function of time at 150 Gev ans is part of the study listed above.

Can we use the Beam Line Tuner (BLT) to measure the coupling by looking at BPM turn by turn data?

Valeri suggested that we can measure the tunes and coupling of the Tevatron if we could collect TBT data from several of the BLT BPMs after we give the beam a small kick. This type of measurement would make it much easier to study the tunes and coupling at 150 Gev while the machine parameters are varying and could also be used to measure the tunes and coupling at various points in the Tevatron ramp.

Implementing this technique requires the ability to use the injection and abort kickers to give a small kick to the beam. Bruce Hanna can be helpful in this regard by learning how to set up the kicker timing and trigger hardware to give small kicks to the beam. For this technique we would want to kick beam in both the horizontal and vertical planes and for the kicks in each plan measure the BPM TBT in both the horizontal and vertical plane.

Write procedure for tuning up 150 Gev conditions during shot setup

With Yuri new method of using the octupole circuits tuning up the Tevatron tunes at 150 Gev during shot setup becomes more important. Yuri has been in the control room quite often these past several weeks making these tune adjustments but we wish to turn this responsibility over to the operations group during shot setup. Yuri and Jerry will write up a procedure which can be used by the operators during shot setup.

BPM TBT measurements

It would be useful to have the TBT capability of all the Tevatron BPMs working. With these working, analysis of the Tevatron lattice, including coupling effects, could be performed. We are supposed to be getting the hardware and software setup for this but we are unsure of the status. Ming Jen and Xialong Chen may be able to help us and look into this. We could need about 8k turns of data to extract the tunes to within 0.001 and look at coupling effects.

Is the tune drift at 150 Gev related to the tune excursions at the start of the ramp?

The time constant of the tune and coupling drifts at 150 Gev is similar to the time drift of the b2 fields and chromaticity compensation. Also the b2 unwind at the start of the ramp finishes playing out at about 6 seconds into the start of the ramp. This is at about 153.5 Gev which also happens to be the time with the largest tune excursion at 150 Gev. Recently an extra breakpoint was added at 153 Gev in order to compensate for this tune excursion. Is it possible that the tune excursions we are seeing at the start of ramp are related to the drift at 150 Gev analogous to the b2 correction?

Possible Theories to explain tune drifts.

1) Combination of orbit drifts and sextupole fields are causing a feeddown effect.
2) There is a failure of a single element which is behaving badly. For instance a dipole with a shifted coil package?
3) Does 980 Gev operations (versus 900 Gev in Run I) have anything to do with this?
4) Changed about 20 dipoles (out of 774) in preparation for high energy running. Did this change the harmonics in any way?